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RYAN MODEL 534

VEHICLE RANGE EXTRACTION UNIT

FINAL ENGINEERING REPORT

1 MARCH 1964

Prepared Under NASA Contract NAS8-5481

Report No. 53463-8

RYAN ELECTRONICS

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George C. Marshall Space Flight Center

Ryan Report No. 53463-8

Final Report

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RYAN ELECTRONICS

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I INTRODUCTION.

A. Contract Requirements

Contract NAS8-5481 covering the design, development and fabrication of one Vehicle Range Extraction Unit (VREU) for use in a design study of the Automatic Ranging and Orbit Determination (AROD) system was signed between the George C. Marshall Space Flight Center and Ryan Aeronautical Company on 10 July 1963. This contract required that (a) Ryan perform experimental design and development of the VREU and (b) fabricate one VREU as a working model for use in a design study of the AROD System. Final inspection and acceptance to be accomplished at the George C. Marshall Space Flight Center. Monthly progress reports were required in narrative form, brief and informal in content. The reports include (a) a quantitative description of overall progress, (b) an indication of any current progress problems and (c) a discussion of the work to be performed during the following monthly reporting period. In addition, a final report is required which summarizes the results of the entire contract work including recommendations and conclusions based on the experience and results obtained.

B. Contract Change

Early in the program, Ryan submitted a proposal to modify the original requirements for the VREU. This modification included the addition of buffer storage devices between the active up-down counters and telemetry equipment; a quantity of two VREU'S, each with two channels of range extraction units; and twelve output emitter followers from each channel to isolate binary information between the active up-down counters and the command logic subassembly. The MSFC Contracting Officer's Representative also requested the addition of 20 monitoring points in the VREU. The points to be monitored included the 16 range tone inputs from the receiver, the reference signal input, and the power supply voltages. Contractual go-ahead to incorporate the modifications as proposed was received during September 1963. The modifications were included in the detailed equipment requirements as specified in AROD specifications Nos. 5 and 6. These specifications are reproduced in full in Appendix 1.

C. AROD System

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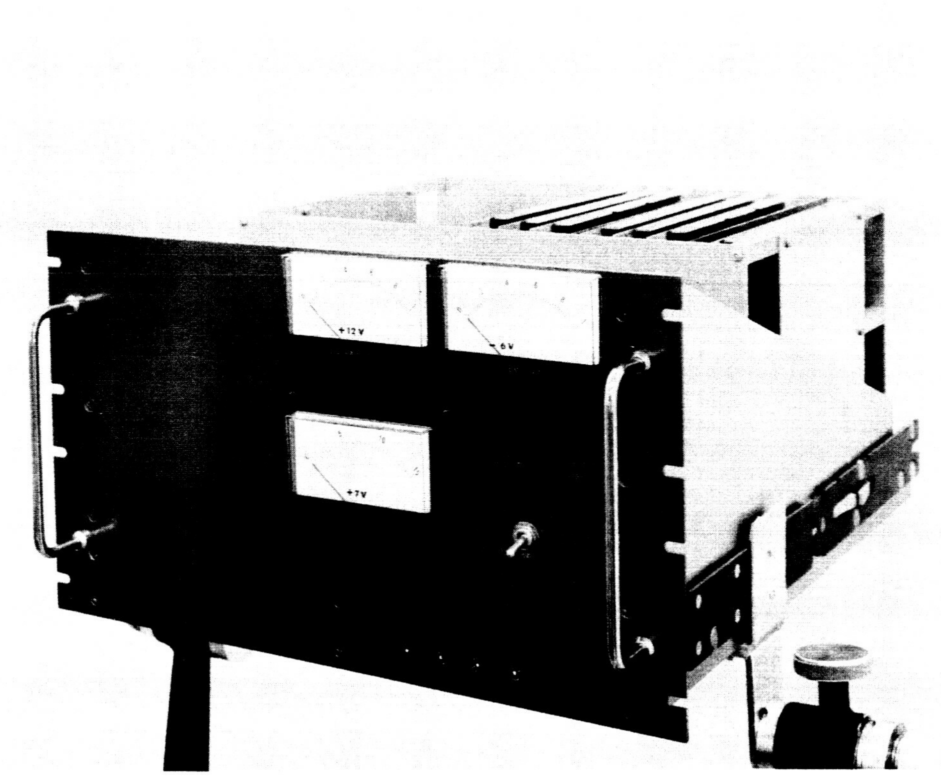
The Vehicle Range Extraction Unit (see Figure 1) is a part of the vehicle-borne portion of the AROD System. The AROD System is being developed to fulfill the need for an accurate, flexible tracking system for space vehicles. The vehicle borne equipment includes a continuous wave transmitter which communicates with multiple, unattended ground transponder stations to provide precision vehicle position and velocity. Range and velocity measurements are made with respect to three or more precisely located transponder stations. The velocity of the vehicle relative to a ground transponder station is determined by measuring the doppler frequency shift of the



VEHICLE RANGE EXTRACTION UNIT

Figure 1

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coherent carrier transmitted from the vehicle to the transponder and back. The range of the vehicle relative to the transponder station is determined from the signal propagation time delay and is measured by the VREU by phase comparisons between the transmitted and received modulation tones on the carrier. These measurements are time labeled and either telemetered to earth or used directly to compute the actual position and velocity of the vehicle in orbit. Author

D. Vehicle Range Extraction Unit

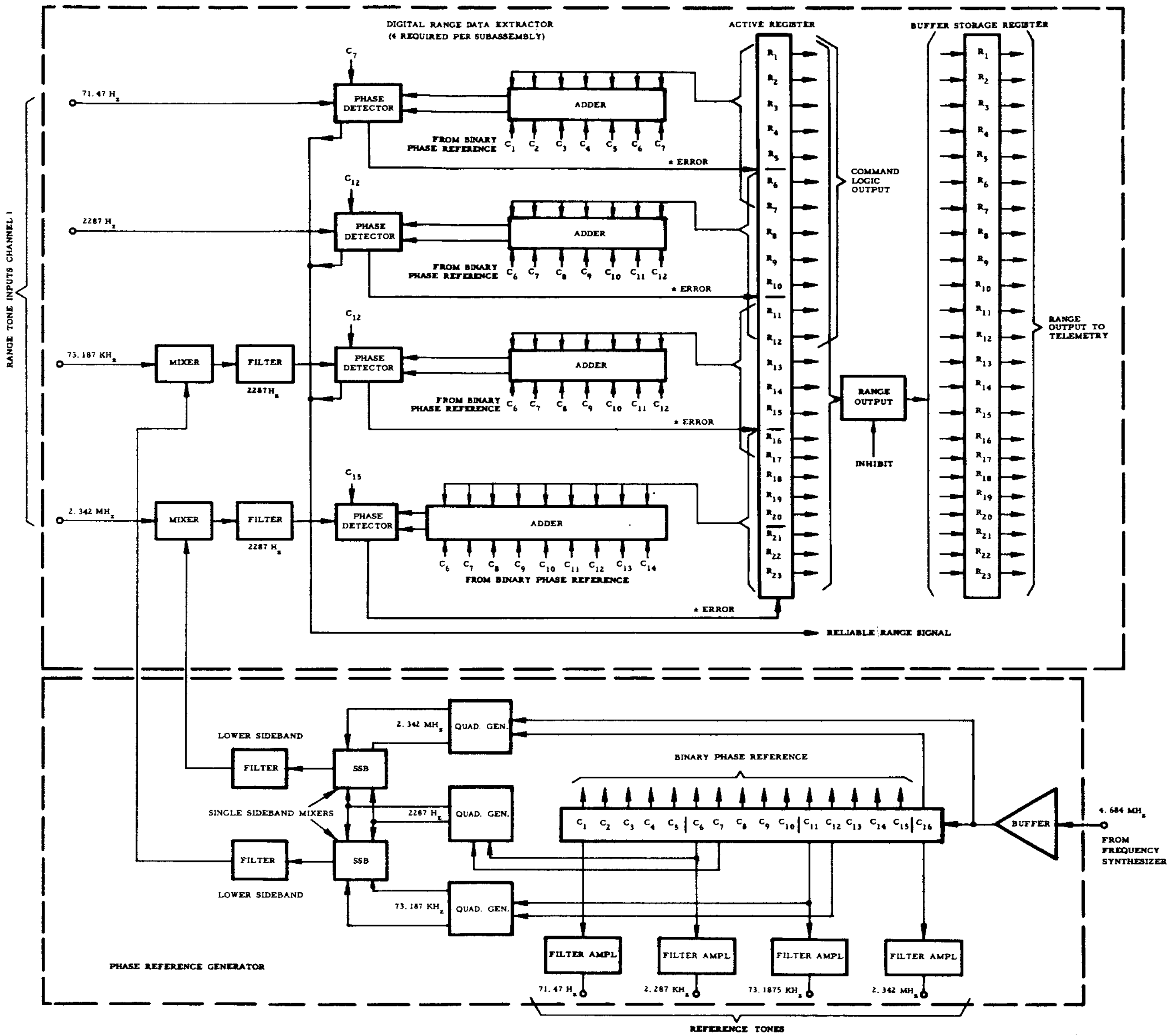
The Vehicle Range Extraction Unit includes four identical range information channels and one phase reference generator common to the unit. Each channel receives four range tone inputs from a corresponding channel of the AROD System receiver. Of the four range tones, the high frequency tone provides fine range resolution while the two intermediate frequency tones and one low frequency tone provide range ambiguity resolution. These tones originate in the phase reference generator but are delayed in time due to transmission to and from a given transponder station. In addition to providing the four system reference tones, the phase reference generator provides all the phase references needed in the VREU. Each channel of range extraction equipment must determine and present the time delay or range in binary digital form as measured from the phase difference between the received range tones and the reference tones with the stipulation that analogue to digital encoders must not be used. The readouts are transferred in parallel binary form to storage registers which can interface with telemetry equipment or with a guidance system. The transfer is triggered by a range data transfer pulse generated elsewhere in the AROD System to enable time correlation of the range data with other data being generated by the system. In addition, a portion of each range number is directly available to the Command Logic Unit of the AROD System. Updating of the range numbers is inhibited during transfer to the telemetry buffer storage and when being sampled by the Command Logic Unit. Each channel provides a reliability signal to indicate that the range number is formed correctly from the data presented.

II TECHNICAL APPROACH

A. General

The Vehicle Range Extraction Unit is operational digital in nature. It consists primarily of four identical channels of digital phase tracking equipment and one digital phase reference generator which is common to the unit. A functional block diagram of the equipment is shown in Figure 2.

The phase reference generator receives a reference tone from the vehicle system's master oscillator. This tone is processed by a squaring amplifier to provide triggers to a chain of binary scalers. The scalers develop a sixteen bit parallel binary word or number that continuously cycles from its maximum value to its minimum value.



VEHICLE RANGE EXTRACTION UNIT
(Block Diagram)
Figure 2

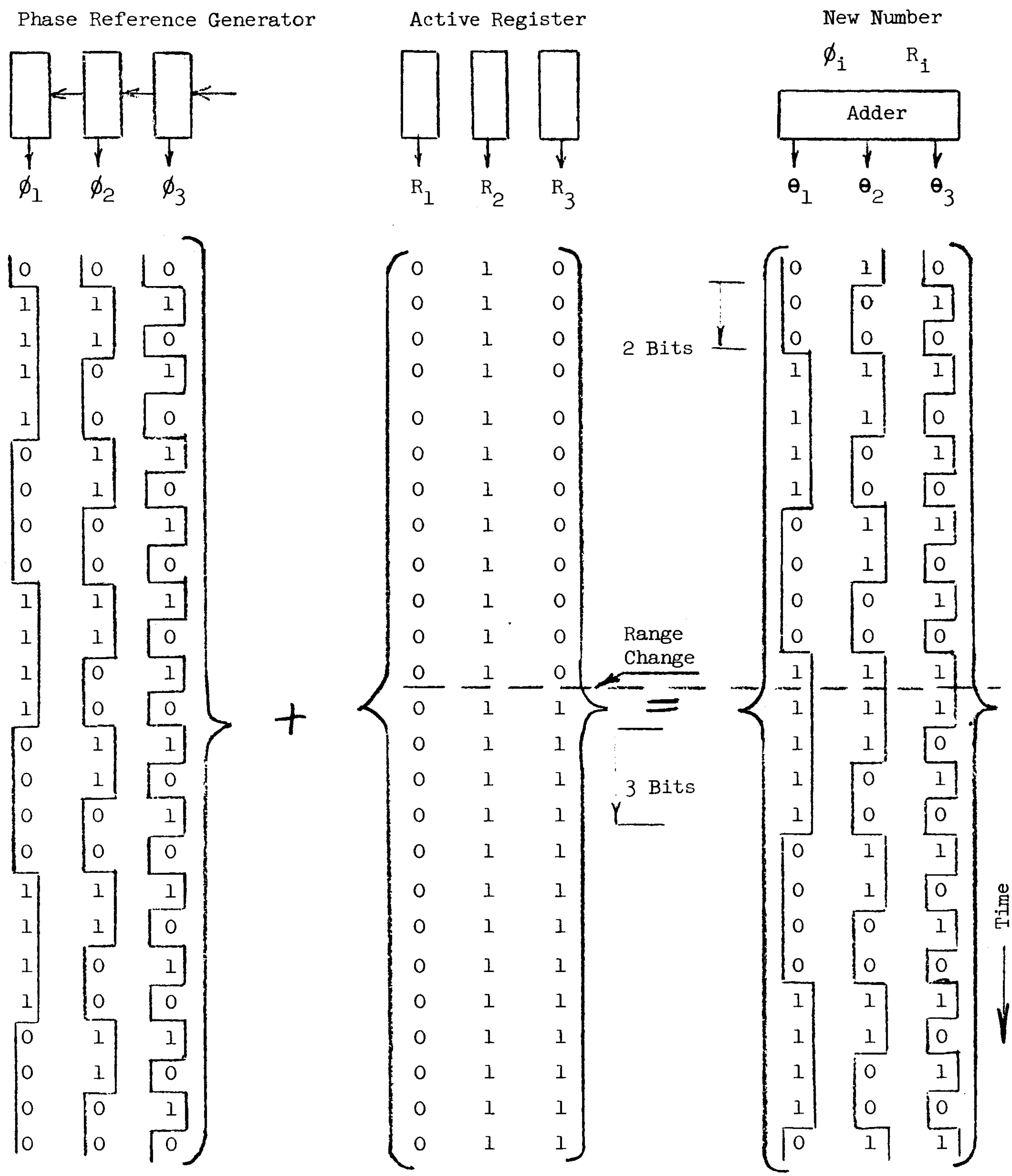
Sections of this number are used as digital phase references of various cycle periods for the digital phase tracking loops in the range extraction channels. The number is also tapped at the appropriate locations to obtain the four reference tone signals for use in the transmitter modulator. Two additional tones are developed in single sideband mixers for use in the range tracking channels.

Each channel of range extraction equipment continuously tracks its four range tone inputs with digital phase tracking loops which keep the twenty-three bit binary range number updated in real time through the application of an operational digital technique. This technique is described in the paragraph on digital phase trackers. In essence, a section of the range number is inside each tracking loop. The phase reference signal to that loop is shifted in phase by a fraction of a cycle proportional to the binary number in that section. This phase shifted signal is compared with the respective range tone input in a discriminator which commands the updating of the number in that section until the phase error is below a set threshold. The number in that section thus is a measure of the phase difference between the reference signal and the range tone. The range number, however, is not made up of independent sections with independent tracking loops. Rather, each range tone tracking loop is overlapped with that of the next higher frequency range tone through the ADDER section so that after the initial range ambiguity resolution has been performed, the entire range number is only updated by the fine range tone tracking loop.

The two lower frequency range tones of each channel are directly processed by squaring amplifiers and sent to their respective digital phase tracking loops. The two higher frequency range tones are first mixed with other reference tones from the phase reference generator to get a lower frequency signal with the correct phase information before going to their digital phase tracking loops.

B. <u>Digital Phase Tracking Loops</u>

The phase tracker is a servo device that compares the phase of an incoming signal with the phase of a feedback signal and then uses the difference or error to correct a phase output signal and the feedback signal until the error is zero or below a set threshold level. The digital phase trackers perform this function by shifting the phase of the feedback signal in quantized steps controlled by a parallel binary number stored in an active register. The active register is updated by an error signal which will increase or decrease the stored number until the error signal is below a threshold. The zero error condition implies that the feedback signal is in phase with the input signal and that the updated number in the register is proportional to the phase shift required to cause this condition. The manner in which digital phase shifting is accomplished is demonstrated in Figure 3. In the demonstration, a three bit binary number from a phase reference generator is continuously cycling from its maximum value to its minimum value,



Digital Phase Shifting

Figure 3

numercially from a binary seven to zero. The most significant bit of this number, electrically, is a square wave signal with a frequency period equal to the cycle period of the number. The fundamental sine wave component of this square wave is a reference tone which will be transmitted to a transponder and returned with a phase lag relative to the reference tone. In Figure 3, a fixed binary number, stored in an active register, is numerically added to the cycling phase reference number to produce a new number. The new number is also cycling in the same manner and with the same period as the phase reference number. However, the most significant bit of this new number is a square wave shifted in phase relative to the most significant bit of the phase reference number. The magnitude of the phase shift is a binary fraction of the cycle period and equal to the fixed binary number in the active register. In the demonstration of Figure 3, the fixed number is first a binary two giving the ADDER output a most significant bit shifted to lag the phase reference by two parts of the eight bit period. The fixed number then is changed to a binary three, and the ADDER output lags the phase reference by two parts of the eight bit period. The fixed number then is changed to a binary three, and the ADDER output lags the phase reference by three eighths of a cycle. The most significant bit of the ADDER output is the feedback signal for a digital phase tracking loop. The next most significant bit of the ADDER output is also used in a discriminator for determining a lead or lag condition.

C. Phase Discriminator

The phase tracking loop must have a phase comparator which can detect the phase error magnitude between the incoming signal and the feedback signal and also determine whether the phase error is due to a leading or lagging condition. These functions are performed by a digital discriminator which comprises a logic exclusive OR gate, a threshold gate, a lead gate and a lag gate. The input signal to the phase tracking loop, which is one of the range tones from the AROD system receiver, is first processed by a squaring amplifier to make it a square wave signal or binary element which at any given time is either a ONE or a ZERO. This signal and the feedback signal are compared in a logic exclusive OR gate which gives a logic ONE output whenever the two inputs are different, and a logic ZERO output otherwise. Thus, if the two square waves are of different phase, the exclusive OR gate will give a logic ONE output every half cycle. The exclusive OR gate function is demonstrated with the various waveforms in Figure 4.

A threshold function is obtained electrically by giving the exclusive OR output signal a slow rise time and fast fall time as shown in Figure 4. The slow rise time, coupled with the inherent voltage threshold of the following logic AND gate, used for the lead/lag determining function, will require the error output of the exclusive

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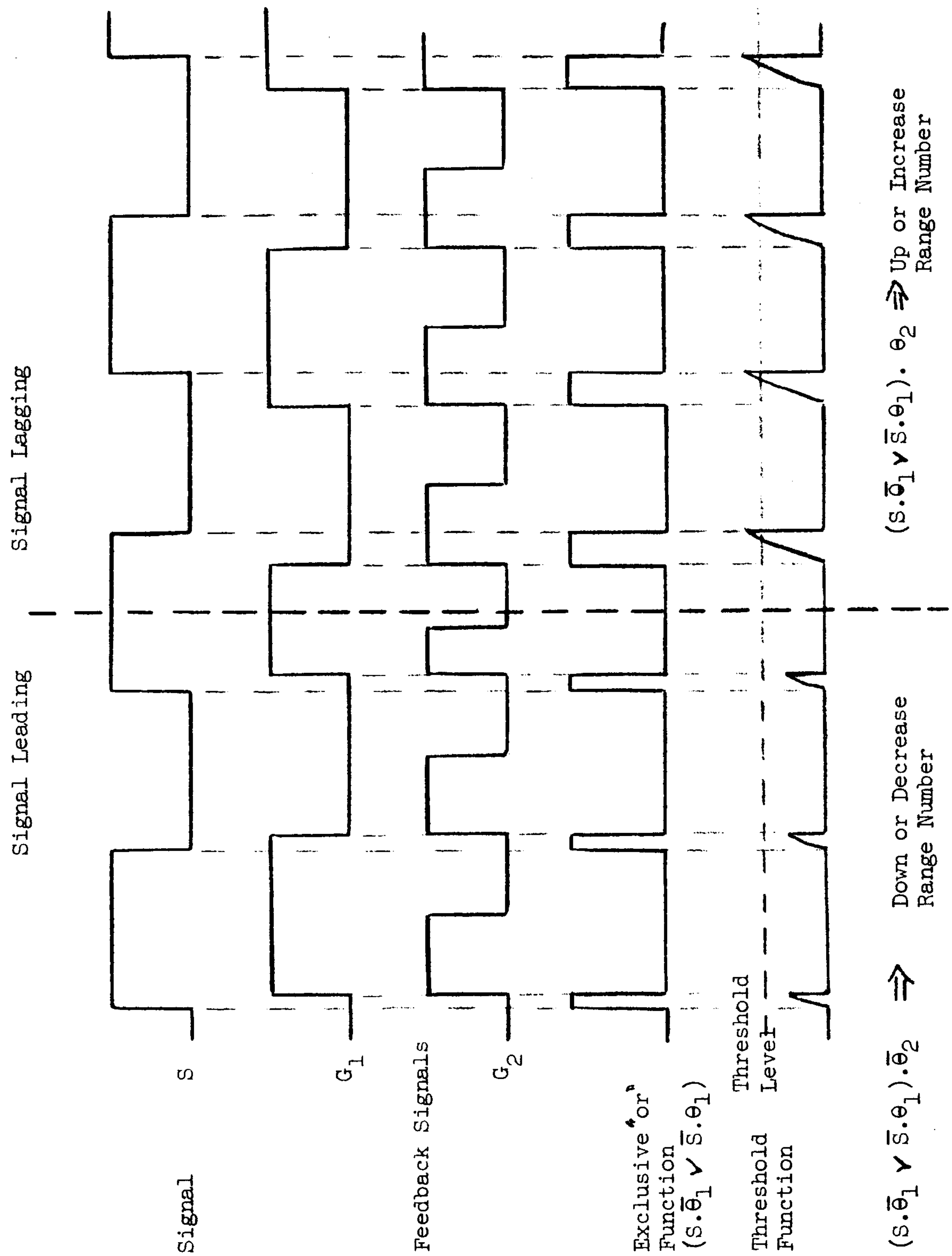

Wave Form Diagram of Discriminator Function

Figure 4

OR gate to persist long enough to build up to the voltage threshold. This is an analogue function and not the only way to obtain the threshold, but it is used in the developmental model because of its adequacy and ease of instrumenting with the logic circuits used.

The phase lead or lag determination is accomplished by gating the error output with the second most significant bit output from the ADDER of the digital phase shifter. This function is demonstrated with the signal waveforms shown in Figure 4. The ADDER output number cycles with decreasing value in the same manner as the phase reference input, as demonstrated in Figure 3. Also, an increase in the "fixed" number stored in the active register causes the feedback to increase in phase lag. Therefore, when the phase error signal from the exclusive OR gate occurs while the second most significant bit is a one, the input signal is lagging the feedback signal, and clock pulses are gated into the active register to increase its number and causes the feedback to shift in the lag direction. In like manner, when the phase error occurs while the second bit is a zero, the input signal is leading the feedback signal and clock pulses are gated by the complement of the second bit causing the active register to decrease its number, thus shifting the feedback in the lead direction. A discriminator constructed in this manner will perform properly over a complete cycle of the signal frequency.

D. Active Register

The active register is an up-down counter composed of binary scalers which are gated as a "ripple through" counter to trigger the next stage from "ONE'S" side of the trailing edge of the waveform to count up and they are gated to trigger from the complementary or "zero" side to count down. The up-down control is a direct coupled flip flop controlled by the discriminator. Clock pulses of a sufficiently high rate are gated into the counter whenever the discriminator threshold gate fires. This clock pulse rate, in part, determines the servo loop gain for the digital phase trackers.

E. Reliable Range Number Indication

A reliable signed bit is associated with each range number. A binary ONE indicates that the range number is properly formed to the extent that the range tones are being tracked and the range ambiguity has been resolved. The reliability signal is derived from the error signals of the three lower frequency range tone trackers. These signals are added in a logic OR gate and presented to a Schmitt device which fires above a set threshold. The Schmitt then drives a time delay network which will hold the reliable output in the off or zero condition for a set period. If any one of the three discriminators fires every seven milliseconds or at a faster rate, the reliability signal will be held at zero. The time period is long enough to assure that the low frequency range tone is being tracked. The time period is also long enough to require that all four range tones are phase coherent. The fine range tone tracker is also included because a random fine range tone signal will cause the adjacent tracking loop to see a random least significant bit due to the tracker overlap described previously.

F. Frequency Converters

The fine range tone frequency of 2.342 MH_Z and the range resolution tone frequency of 73.1875 KH_Z are mixed with phase coherent tones developed in the phase reference generator. The difference frequencies are then filtered out and used as the signal inputs for the respective tracking loops. Each difference frequency is at 2.287 KH_Z. The phase or range information carried by each range tone is conserved by the mixing process (see Appendix II), but the sampling rate of the phase data is reduced because the discriminators used with the trackers check the phase only at the zero crossings of the difference frequency. The advantage gained by mixing is the reduced speed required for the digital elements. The clock rate required without mixing would be about 600 MH_Z.

G. Telemetry Transfer Signal

A telemetry transfer signal is developed in the AROD Vehicle system that is used to "time table" the data. When the Vehicle Range Extraction Unit receives a transfer pulse, all discriminators in all four channels are momentarily inhibited to prevent updating of the range numbers and the range numbers in the active registers are non-destructively transferred to the buffer storage registers. The previous number in each storage register is cleared at the same time. The buffer storage registers are composed of direct coupled flip flops which are momentarily slaved to their respective active register flip flops during the transfer pulse and are inhibited at all other times.

H. Command Logic Output

The range number outputs to the Command Logic Unit of the AROD System consist of the twelve most significant bits of the active register of each channel. The numbers are available at all times. However, the command logic equipment develops an inhibit pulse which inhibits all discriminators in the VREU to prevent updating of the range numbers during the moment these range numbers are being monitored.

III GENERAL FACTUAL DATA

Each channel of the Range Extraction Unit derives the range and resolves the range ambiguities from the phase data carried by the four range tone inputs. The range is then presented in parallel binary number form as the output. Each range tone is tracked using digital phase locked loops which include a portion of the binary range number in each loop. The phase tracking loops are tied together through the range number and each adder section in a way which causes the lower frequency or range ambiguity resolving loops to be dependent, within limits, upon the high frequency loop which tracks the fine resolution tone. This feature is preserved as long as the coarse range tones maintain phase coherences within phase error limits with a 3σ value of about ± 5 degrees.

A. Range From Phase Data

The four phase reference tones developed by the phase reference generator are modulated on a coherent microwave carrier frequency and transmitted from the vehicle to a transponder station. The transponder in turn removes the modulation tones from the carrier and places them on a new carrier frequency developed in a precise manner to preserve the phase and doppler information for the first half of the journey and then transmits back to the vehicle where the tones are removed in the corresponding receiver channel and returned to the VREU. Each range tone has thus made a round trip to the transponder and has experienced a time delay relative to the time advanced reference tone. The time delay has a value twice the one way range divided by the speed of light or radio propagation. The phase lag, θ, experienced by any one of the tones is equal to the frequency of the tone multiplied by the delay time.

$$\theta = f \frac{2R}{C} \text{ cycles}$$

The phase lag may be several cycles plus a fraction of one cycle depending on the range tone frequency. The number of full cycles of shift experienced by a higher frequency tone can be resolved by measuring the phase shift of a lower frequency tone to the extent that one cycle of the lower frequency is several cycles of the higher frequency tone.

B. Optimum Range Tone Frequencies

The frequency of the coarse range tone must be low enough so that the desired maximum range will not cause the phase lag to be greater than one cycle of the coarse tone. The number of range tones used and their frequencies can be based on criteria governed by the phase jitter expectation on the coarse tones, the phase measuring resolution of the equipment and the sampling rate desired in cases where the phase is sampled only at the zero crossings of the range tones. This method is used in the developmental model's digital discriminator. The choice of optimum range tone frequencies, however, was not a prerogative in the design of the developmental model of the range extraction equipment. The sampling rate of the fine range tone was a choice made during the design of the development model. This high frequency tone is mixed down to a frequency of 2.287 KH_z. If the vehicle range is changing at a maximum rate of 9,000 meters per second, the change in range between each half cycle sample will be 1.8 meters. The range error is reduced to zero during each sample so that the active register is updated in quantized steps of about 1.8 meters. The transfer of the buffer storage, however, may occur at any time between sample periods because the transfer trigger is generated elsewhere in the AROD system. This situation leaves an uncertainty in the range readout to the storage register during the maximum range rate. This condition can be avoided by mixing the fine range tone down to a frequency of 18.296 KH_z to increase the sample rate. The use of this frequency will provide quantized range steps no greater than 0.25 meters at the maximum range rate. This is equivalent to reducing a servo system's dynamic lag and can be accomplished in the present digital phase trackers by increasing the phase reference generator number by one bit and increasing the reference frequency.

C. Binary Range Number

The range number of each channel of the Vehicle Range Extraction Unit is required to be a parallel binary number large enough to represent a range of 2097 kilometers with a bit resolution of 0.25 meters. A twenty-three bit binary number satisfies these requirements. The most significant bit of this number represents a range value of 2^{20} meters or 1048.576 kilometers. The least significant bit represents a range step of 2^{-2} or 0.25 meters. When all of the bits of this binary number are "ones", the total range represented is 2,097,151.75 meters. This range number can be expressed by a maximum value R_m multiplied by a binary fraction between zero and one as represented by a summation:

$$(1) \qquad R = R_M \sum_{K=1}^{N} \frac{\delta_K}{2^k}$$

where the δ_k's are either ones or zeros and where

$R_m = 2^{21}$ or 2,097,152 meters. $\qquad N = 23$

The binary range number stored in the active register of each channel of the range extraction equipment is such a number. It can be separated into the sum of four sections corresponding to the four range tone frequencies used, thus:

$$(2) \qquad R = 2^{21} \sum_{K=1}^{5} \frac{\delta_K}{2^K} + 2^{16} \sum_{K=1}^{5} \frac{\delta_{K+5}}{2^K} + 2^{11} \sum_{K=1}^{5} \frac{\delta_{K+10}}{2^K} + 2^{6} \sum_{K=1}^{8} \frac{\delta_{K+15}}{2^K}$$

Now, since the propagation time delay, τ, is equal to the value given by:

$$\tau = \frac{2R}{C}$$

The binary range number is substituted for the range in the time delay expression, giving:

$$(3) \qquad \tau = \frac{2^{22}}{C} \sum_{K=1}^{5} \frac{\delta_K}{2^K} + \frac{2^{17}}{C} \sum_{K=1}^{5} \frac{\delta_{K+5}}{2^K} + \frac{2^{12}}{C} \sum_{K=1}^{5} \frac{\delta_{K+10}}{2^K} + \frac{2^{7}}{C} \sum_{K=1}^{8} \frac{\delta_{K+15}}{2^K}$$

Each section in this summation is multiplied by a coefficient just equal to the reciprocal of the corresponding range tones. The time delay expression can thus be written as:

$$(4) \quad \tau = \frac{1}{f_4} \sum_{K=1}^{5} \frac{\delta_K}{2K} + \frac{1}{f_3} \sum_{K=1}^{5} \frac{\delta_{K+5}}{2K}$$

$$+ \frac{1}{f_2} \sum_{K=1}^{5} \frac{\delta_{K+10}}{2K} + \frac{1}{f_1} \sum_{K=1}^{8} \frac{\delta_{K+15}}{2K}$$

where: $f_1 = 2^{-7}C$ or $2.3420\ MH_z$

$f_2 = 2^{-12}C$ or $73.1874\ KH_z$

$f_3 = 2^{-17}C$ or $2.2871\ KH_z$

$f_4 = 2^{-22}C$ or $71.47\ H_z$

when $C = 3.99776 \times 10^8$ meters per second.

Each section of the time delay number, equation (4), is some binary fraction of the associated frequency. Also, each least significant bit of a section is one complete cycle period of the next adjacent higher frequency.

D. - Range Ambiguity Resolution

The first coarse range tone experiences a phase lag given as a binary fraction of a cycle equal to -

$$f_4 \tau = \sum_{K=1}^{5} \frac{\delta_K}{2^K} + 2^{-5} \sum_{K=1}^{5} \frac{\delta_{K+5}}{2^K}$$

$$+ 2^{-10} \sum_{K=1}^{5} \frac{\delta_{K+10}}{2K} + 2^{-15} \sum_{K=1}^{8} \frac{\delta_{K+15}}{2^K}$$

Only the first five most significant bits of this phase shift will be updated by the coarse range tone tracker because the remainder is a fraction (less than one cycle) of the next higher frequency tone and thus can be resolved by its frequency tracker. The feedback signal for the coarse tone tracker, however, is shifted by a part of the remainder so that the tracking loops will not be completely independent. This overlap is two binary bits in the developmental model. Thus, the feedback signal is updated in steps of 2^{-7} parts of a cycle, while the tracking loop is only responsible for phase shifts of 2^{-5} parts of a cycle or greater.

The discriminator of this tracking loop has a threshold gate which is set so that the phase error between the range tone input and the feedback signal must exceed a value of about three quarters of the least significant bit controlled by the tracker or about 8.4 degrees of phase. This threshold value coupled with the effect from the feedback overlap allows a clear phase jitter region for the input signal of ± 5.5 degrees. In the second tracking loop, the phase shift experienced by the next range resolution tone, f_3, is equal to:

$$f_3 = 2^5 \sum_{K=1}^{5} \frac{\delta_K}{2^K} + \sum_{K=1}^{5} \frac{\delta_{K+5}}{2^K} + 2^{-5} \sum_{K=1}^{5} \frac{\delta_{K+10}}{2^K} + 2^{-10} \sum_{K=1}^{8} \frac{\delta_{K+15}}{2^K}$$

The first five bits of this number are counts of one complete cycle of the range tone and cannot be detected by this phase tracker. They are handled by the coarse range tone tracker. Only the five bits of the second section of the number will be updated by this tracking loop but its feedback signal is shifted by an overlapping section as in the first loop. The third tracking loop works in the same manner.

The full active register is gated in a manner that allows each range number section controlled by a tracking loop to be updated by the adjacent higher frequency loop. When the higher frequency, for example, the 2.287 KH_z tone, gradually shifts in phase to complete a full cycle, a count is added or subtracted to the next section. This prevents the discriminator of the next section, for example, the 71.47 H_z tone loop, from "firing" and the phase difference of this loop never exceeds one quarter of a bit error for coherent range tones. Each section of the range number is therefore controlled independently by the range ambiguity resolving loops until the errors are below threshold and from thereafter they are controlled by only the fine resolution tracking loop.

IV DETAIL FACTUAL DATA

A. Equipment Calibration

The Vehicle Range Extraction Unit provides the AROD system transmitter with four reference tones which are transmitted to a transponder and returned as range tones with phase shifts proportional to the range to the transponder. The range number of any one of the channels should therefore read zero range if the four reference tones are coupled directly to that channel as range tone inputs.

There are several locations in the VREU where filters are used and these filters have been provided with phase adjustments which can be used to avoid the "zeroing" of the phase bias errors caused by the filters. These phase adjustments, however, have limited adjustment ranges so that they cannot be used to remove phase bias errors developed by the entire AROD system. Phase adjustments external to the VREU should be used for day to day calibrations since they duplicate the function of the internal adjustments.

There is a phase and gain adjustment for each of the four reference tone outputs. The reference tones are sine waves which are the filtered fundamental frequency components of their square wave counterparts used as references in the digital equipment. Each filter should be adjusted so that the sine wave output is in phase with the square wave input. The filters used in the developmental model are simple R-C low pass filters which change in gain as well as phase when the phase adjustment resistor is changed. Therefore, a gain adjustment is also provided so that the required signal level can be maintained.

The range tone mixers of each channel of range extraction equipment have a phase adjustment on the reference tone inputs to the mixers. Two reference tones developed by the phase reference generator are common to the four channels.

The high frequency tone (2.34 MH_Z) is mixed with the fine range resolution tone (2.342 MH_Z) to get a difference frequency of 2.287 KH_Z which is filtered before going to the phase tracking equipment. The second reference tone has a frequency of approximately 70.9 KH_Z and is mixed with the 73.187 KH_Z range tones. A phase shift of these tones is equivalent to a phase shift of either the range tone or the filter following the mixers. These mixer phase adjustments permit small phase corrections in the two higher range tones of each channel. No phase adjustments are provided for the two lower frequency range tones of each channel.

Procedure

A special display is required for readout of the range number. This equipment should be able to display the twenty-three bits of the range number plus one bit for the reliability indication. Also, a pulse generator is required to simulate telemetry transfer pulses to continuously transfer the range data into the buffer storage registers. The pulse generator should deliver a five volt pulse of about five microseconds duration at a pulse rate arbitrarily set at two hundred pulses per second. The reference tone input to the VREU is also required and must be from a stable frequency source of 4.684 MH_Z because the filters in the equipment change in phase with a change in frequency.

The calibration test setup is shown in the block diagram, Figure 5. Four short coaxial cables are used to connect the

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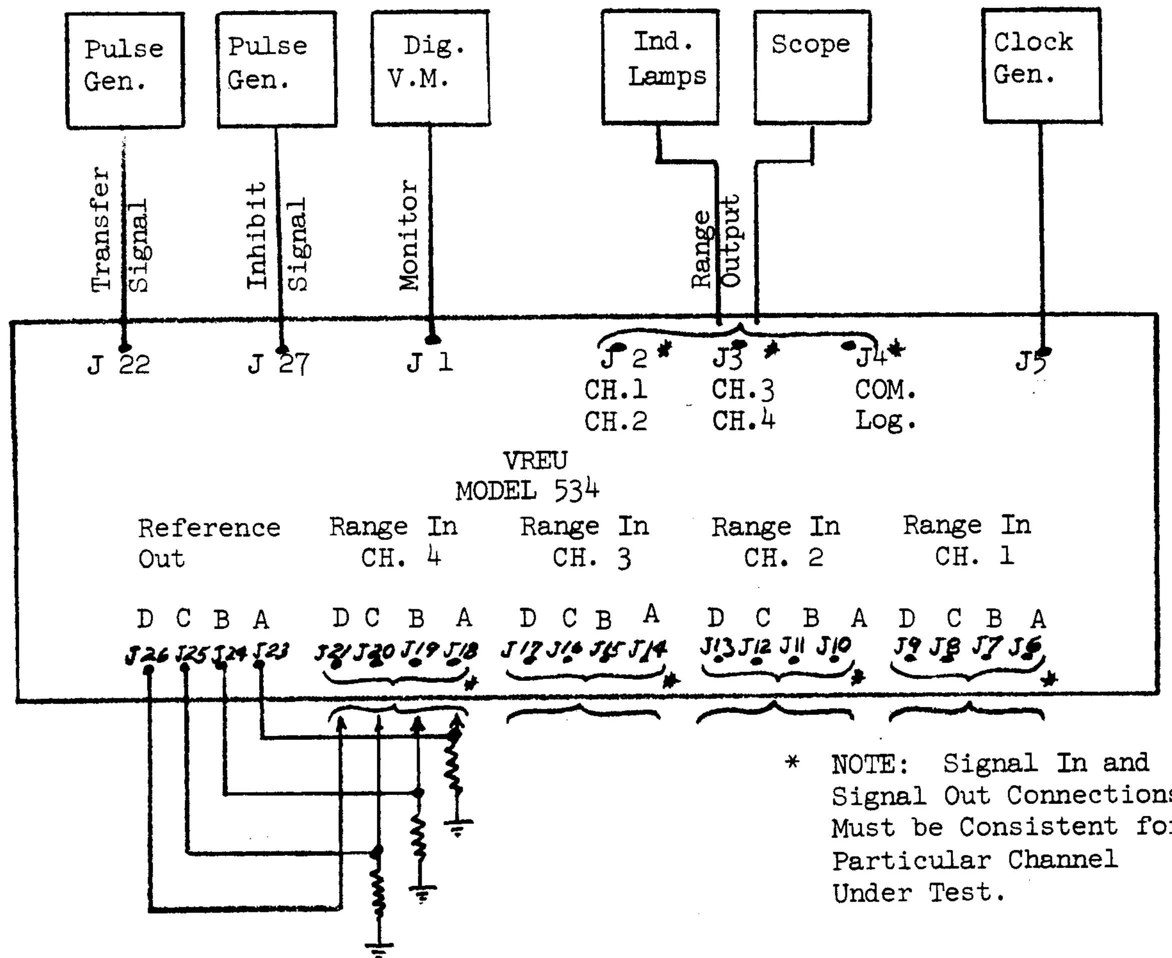


* NOTE: Signal In and Signal Out Connections Must be Consistent for Particular Channel Under Test.

Calibration and Test Set-Up

Figure 5

reference tone outputs to the data channel being calibrated. The three lower frequency tone outputs should be terminated by fifty ohm resistors. The high frequency reference tone inputs of each channel are already terminated with fifty ohm loads.

A scope can be used to set the gain adjustments so that the output tones have a peak to peak value of two volts within one db. The gain adjustments are located on the phase reference generator motherboard and are identified as follows:

R_1 = gain of 2.287 KH_z

R_3 = gain of 73.187 KH_z

R_6 = gain of 2.342 MH_z

The gain adjustment, R8, for the 71.47 H_z tone is on the PC board under the chassis. The phase adjustment resistors are located on the phase reference generator motherboard and are identified as follows:

R_2 = phase of 2.287 KH_z

R_4 = phase of 73.187 KH_z

R_5 = phase of 2.342 MH_z

The phase adjustment, R_4, for the 71.47 H_z tone is also on the PC board under the chassis.

The phase adjustments are varied until the range readout lights are extinguished, indicating zero range. The higher frequency tones should be zeroed first because the range number is not made up of independent sections. The zero of each range tone can be viewed on an oscilloscope by monitoring the discriminator outputs of each channel (D_1, D_2, D_3 and D_4).

The high frequency range tone controls the eight least significant bits of the range number. The three lower frequency tones each control five bits of the range number increasing in significance with the decreasing range frequencies. The reliable data light will come on when the number is properly zeroed. The phase adjustment of the two higher frequency range tones can be aided by adjusting resistors on the third motherboard of each channel. These resistors are identified:

R_7 for the 2.342 MH_z tone,

R_8 for the 73.187 MH_z tone,

All four channels must read zero range for the same reference tone settings.

B. <u>Program Activities</u>

The program was initiated by reviewing the equipment requirements and evolving a program plan. The equipment specification was written utilizing information in the specification issued by MSFC. Following issuance of the program plan and specification, a design concept review was held. Ordering of parts and breadboarding of circuitry was then begun. Certain modifications to the Vehicle Range Extraction Unit were anticipated early in the program and a proposal covering the modifications was submitted, as requested, to MSFC.

The modification quote submitted included the addition of buffer storage devices between the active up-down counters and telemetry equipment; a quantity of two units, each with two range extraction channels, and 12 output emitter followers from each channel to isolate binary information between the active up-down counters and the command logic subassembly and provision for 20 monitored points.

Ground rules for system and equipment design were established between MSFC and Ryan representatives early in the program. These ground rules are summarized below:

1. - A floating grounding system was desired with provisions for grounding the system at one central point.
2. - All monitored outputs must be short proof (power supplies excepted).
3. - All input impedances to be 10 K ohms or greater and all output impedances to be less than 100 ohms. Note: This was later amended to require an input impedance of 50 ohms on the 2.342 megacycle range tone input and 500 ohms on the three other range tone inputs. It was further amended to include an output impedance of 50 ohms for the reference tone outputs.
4. - Connector pin assignments were arranged so that the first pin carries the common line.
5. - A buffer storage erase pulse was not required because the VREU uses flip flop storage devices.

6. MSFC to provide reference designation and drawing number information.
7. The equipment was designed to mount on a standard Emcor heavy duty 19" relay rack, type XRH-21-19-19. Ryan furnished the Jonathan type 150-Q-DB chassis slides.

Ryan investigated the need for isolation between the 12 active up-down counters and the command logic subassembly. It was determined that there was the possibility that the circuits would operate properly without isolation but there was the risk of triggering the active up-down counters by transients on the output lines. The isolation circuitry was included in the design.

Power supply requirements were determined early in the program. It was decided that the following power supplies would be required: - Plus 12 volts DC @ 3/4 amp.; plus 7 volt DC @ 12 amp.; minus 6 volts DC @ 3/4 amp. MSFC representatives requested that the plus 7 volts level be changed to plus 6 volts. The plus 7 volt level could be changed to plus 6 volts if the output signal level to telemetry could be changed to 5 plus or minus 0.5 volts DC instead of 5.5 plus or minus 0.5 volts DC. Since this requirement could not be changed the power supply level was retained at plus 7 volts DC.

AROD Spec. 6, dated 26 August 1963 included the requirements for the modifications quoted by Ryan early in the program. This specification also included the requirements for the use of Type TNC connectors in place of Microdot connectors.

The following connectors were selected for use in the VREU:

Quantity	Connector Type	Function
1	TNC	Reference Frequency Input
16	TNC	Range Tone Inputs
1	TNC	Range Data Inhibit Input
1	TNC	Telemetry Data Pulse Input
4	TNC	Reference Tone Output
1	Bendix Pygmy PT02SE-24-61S	Output to Command Logic
2	Bendix Pygmy PT02SE-24-61S	Telemetry Output
1	Bendix Pygmy PT02SE-16-26S	Monitoring Points
1	Hubbell Type Number 7486	Power Input

Power supplies selected for the Vehicle Range Extraction Unit are Technipower models S-7.3-120A, S-12.0-0.750A and S-6.0-0.750A. At the request of MSFC, Ryan incorporated ammeters to measure the current delivered by the power supplies.

Representatives of MSFC and Brown Engineering visited Ryan early in January 1964. The representatives observed operation of the VREU breadboard and were given a description of circuit operation. Discussions concerning the requirements for spare sub-assemblies resulted in a recommendation that a small quantity of each module would be provided on a separate spares order. Drawings used for the manufacture of the VREU were reviewed and it was decided that these drawings would be sufficient for use by MSFC.

During the acceptance tests on Serial #1, a jitter problem was discovered which caused inaccurate readings in the last three stages. This jitter was eliminated and the first VREU was shipped on 21 February 1964. The second VREU was shipped to MSFC on 28 February 1964. In addition, a complete set of drawings including sepia line tracings of schematics, assembly drawings, panel and chassis assembly and block diagrams have been forwarded to MSFC.

V RECOMMENDATIONS

The entire digital portion of the Vehicle Range Extraction Unit can be fabricated using "off the shelf" integrated circuits to reduce the size, weight, and power consumption of the equipment and improve the reliability expectation.

The analog or linear circuits involved in the interface with the transmitter and receiver equipment constitute the weakest portion of the system when considering range accuracy. These circuits could be eliminated or minimized by modifications in the design in some areas of the vehicle equipment. The areas concerned are those involving transmitter modulation and receiver demodulation techniques. As an example, the range tones are not required by the digital range extraction equipment since only the range tone phase errors are used to update the range number. Therefore, the range extraction equipment and the receiver demodulator equipment can be combined to eliminate unnecessary circuitry. The number of range tones per channel can be reduced to three. The fine range resolution tone, (2.342 MH_z), and the coarse range tone, (71.47 H_z), would be the same with an intermediate range ambiguity resolution tone at

9.128 KH_z. The phase sampling rate for the fine range tone would be each half cycle of the 18.297 KH_z frequency for the minimum range resolution of 0.25 meters at the maximum range rate of 9,000 meters per second. Further simplification of the system could be accomplished by using switched frequency - pulse code modulation for a single range ambiguity resolution tone of 71.47 H_z accompanied by a continuous wave tone for fine range resolution. Extensive bandwidth would not be required for the PCM-FM because the rise and fall times of the pulses can be restored with suitable circuitry.

The above modifications would considerably simplify the vehicle system by extending the digital portion of the equipment into the transmitter and receiver circuitry where the use of "off the shelf" digital integrated circuits would result in smaller size and greater reliability.

APPENDIX I

MSFC AROD SPEC 5

MSFC AROD SPEC 6

AROD

Airborne Range and Orbit Determination

VEHICLE-BORNE UNITS
GENERAL SPECIFICATIONS

NO. AROD-SPEC-5

DATE August 7, 1963

ASTRIONICS DIVISION

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

1. SCOPE

1.1. Applicability. This specification sets forth the general requirements for system development models of AROD vehicle-borne equipment, and is applicable to all such equipment.

2. APPLICABLE DOCUMENTS

2.1. Documents. The following documents provide additional information as to requirements toward which design efforts should be directed since these requirements will be imposed on later models of the equipment:

(a) MSFC-STD-154 — Printed Circuit Design and Construction; Standard for

(b) MSFC-PROC-158B — Soldering of Electrical Connections (High Reliability); Procedure for

(c) MSFC-PROC-257 — Conformal Coating of Printed Circuit Assemblies; Procedure for

(d) MSFC Astrionics Division Design Guide Line Procedure 09-5; Design of Electronic Component Housings for Flight Equipment.

(e) AROD-SPEC-2 — Packaging of System Development Models of Vehicle-Borne Equipment

(f) AROD-SPEC-3 — Vehicle-Borne Equipment Tentative Environmental Test Specification

2.2. Availability. Copies of the above listed documents, for use in connection with AROD System contracts, may be obtained from the contracting officer.

3. REQUIREMENTS

3.1. Background. The system development models of AROD vehicle-borne equipment will be used for tests in the laboratories, and will also be operated in an aircraft during flight tests. They will not be placed on a launch vehicle, and thus will not be subjected to launch or space environments. Neither is it necessary that this equipment meet the size and weight limitations of flight hardware. It is intended, however, that the prototype and production models to be later developed as a result of the system development test program will meet all the requirements for flight hardware. All designs for system development units will be designed with this objective in mind.

3.2. Dimensions and Weight. Units shall be of such size that they can be mounted on standard 19 inch rack panels, as required by AROD-SPEC-2. Good design and manufacturing practices shall be followed, so that the units are not excessively large or heavy.

3.3. Environmental Requirements. Units shall meet conditions which would normally be encountered in laboratory and aircraft flight testing conditions.

3.3.1. Temperature. The equipment shall be capable of normal operation in atmosphere at 0° to $+60^{\circ}$ C.

3.3.2. Shock and Vibration. The equipment shall be designed to withstand the normal shocks which would be encountered in shipping and handling, laboratory testing, and aircraft flight testing.

3.3.3. Altitude. The equipment shall be capable of operating at altitudes up to 25,000 feet.

3.4. Power Requirements. The equipment shall be designed to operate from voltages which are easily obtainable from 28 volts DC, which will be basic power source for future equipment. Prior to incorporation of supply voltages into final design, approval to use the voltage levels shall be obtained from MSFC. Power supplies, which in this case will operate from 115 volts AC, will be provided by MSFC.

3.5. Connectors.

3.5.1. Signal Connectors. Unless otherwise specified in individual instances, all signal connectors shall be type N, TNC, or TM, or Microdot screw-type jacks and plugs, types 31 and 32.

3.5.2. Power and Distribution Connectors. All power and distribution connectors shall be AN or MS approved types.

3.6. Test Points. Test points shall be provided as required by specifications for individual units. Additional test points may be added as considered advisable. Test points associated with signal paths shall be green; all other shall be white.

3.7. Monitoring Points. Monitoring points shall be provided as required by specifications for individual units. Additional monitoring points which are considered to be required to provide complete information of important system characteristics shall be added.

3.7.1. Monitoring Outputs. A 0-5 volt DC output proportional to the function being measured shall be provided for each monitoring point. Impedance of each monitoring point shall be 5k ohms or less.

3.7.2. Monitoring Connections. All monitoring points shall be connected ~~through coaxial or shielded wire~~ to a common connector for each unit.

3.8. Components. All components used shall conform to accepted standards of the industry.

3.9. Design. All units shall meet accepted standards of performance and reliability.

3.10. Manufacturing. All units shall conform to accepted standards of workmanship. Components shall not be potted.

3.11. Design Objectives. All design shall be accomplished with the following requirements in view. While these requirements are not binding upon the equipment covered under this specification, no design shall be used which will not allow compliance with these requirements in future models.

3.11.1. Dimensions and Weight. Future units will be required to be of the minimum size and weight which is consistent with meeting the requirements for reliable equipment.

3.11.2. Mounting. Future units will be designed for mounting on thermal conditioning panels, as described in MSFC Astrionics Division Design Guide Line 09-5.

3.11.3. Environmental Requirements. Future units will be required to meet the environmental test requirements for launch and space vehicle equipment; the tentative environmental testing these units will be required to meet is contained in AROD-SPEC-3.

3.11.3.1. Temperature. Future units will be required to operate in atmospheric temperatures ranging from -85° to $+100^{\circ}$ C. Temperature control will be provided by means of thermal conditioning panels, which will be maintained between $+15^{\circ}$ and $+27^{\circ}$ C, which will have a heat-dissipation capability of approximately 5 watts per square inch. These panels are described in MSFC Astrionics Division Guide Line Procedure 09-5.

3.11.3.2. Altitude. Future equipment will be required to operate in an unpressurized compartment in a space environment; that is, it must operate satisfactorily in atmosphere of 10^{-7} Torr.

3.11.4. Power Requirements. Future equipment will be required to operate at optimum efficiency, using a minimum of power. They will operate from 28 ± 4 volts DC, with possible surges up to 40 volts for 10 milliseconds.

3.11.5. Components. Future units will be required to incorporate only components which meet the reliability and quality requirements for use in manned vehicles.

3.11.6. Manufacturing. Future equipment will be required to comply with MSFC-STD-154, MSFC-PROC-158B, and MSFC-PROC-257.

AROD

Airborne Range and Orbit Determination

RANGE DATA EXTRACTION EQUIPMENT

NO. AROD-SPEC-6

DATE 26 August 1963

APPROVED

ASTRIONICS DIVISION

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

1. SCOPE

1.1. This specification is applicable to the system development model of the Range Data Extraction equipment of the AROD System.

2. APPLICABLE DOCUMENTS

2.1. The following document sets forth requirements applicable to the Range Data Extraction equipment:

AROD-SPEC-5	Vehicle-Borne Units, General Specifications

3. REQUIREMENTS

3.1. General.

3.1.1. Background. The Range Data Extraction equipment will be a part of the vehicle-borne portion of the AROD System. Range data must be extracted from four identical channels. A channel will have four range tone inputs which are delayed in phase due to transmission to and from a given ground transponder. The Range Data Extraction equipment must determine and present in binary form the phase difference between the received range tones and the reference tones. Readout will be transferred in straight binary form to a storage register which will interface with telemetry equipment, and at a later date with the guidance system. A range data transfer pulse will be generated elsewhere in the AROD System to enable time correlation of the data being transferred with other data being generated by the System.

3.1.2. Description. The Range Data Extraction equipment shall consist of a basic unit containing a phase-reference generator and four digital range data extractor modules. The range data extractor modules shall be so constructed as to be easily removable and interchangeable for all channels.

3.2. Performance. The equipment shall meet the following performance requirements:

(a)	Maximum range	2097 km
(b)	Minimum range	0 m
(c)	Range resolution	±0.25 m
(d)	Maximum range rate	9000 m/sec

3.3. Reference Frequency Input. The unit shall accept the following reference frequency from the frequency synthesizer:

(a)	Frequency	4.684 MHz
(b)	Amplitude	2.0 v (peak-to-peak, sine wave)±1.0 db
(c)	Input impedance	50 ohms
(d)	Connector	Type TNC
(e)	Number of Connectors	1

3.4 Range Tone Input. The equipment shall accept from the receiver four range tones on each channel, as follows:

(a)	Frequency	2.3420000 MHz 73.1875 KHz 2.2871 KHz 71.47 Hz
(b)	Amplitude	2.0 v (peak-to-peak, sine wave) ± 1.0 db
(c)	Input impedance - 2.342 MHz others	50 Ohms 500 Ohms
(d)	Connector	Type TNC
(e)	Number of connectors	16 (4 per channel)

3.5. Reference Tone Output. The following frequencies, which are generated within the Range Data Extraction equipment for phase-comparision purposes shall also be available as outputs for use in deriving the modulating signals to the transmitter:

(a)	Frequency	2.3420000 MHz 73.1875 KHz 2.2871 KHz 71.47 Hz
(b)	Amplitude	2.0 v (peak-to-peak, sine wave) ± 1.0 db
(c)	Output impedance	50 Ohms
(d)	Connector	Type TNC
(e)	Number of connectors	4

3.6. Range Data Inhibit Pulse Input. The equipment shall accept the following pulse which will inhibit updating of range data during the time data is read by the command logic circuitry. Only one data inhibit pulse will be provided; distribution to each of the four channels shall be made within the Range Data Extraction equipment.

(a)	Amplitude	5.5 ± 0.5 v
(b)	Duration	5 microseconds
(c)	Time between pulses	96 milliseconds
(d)	Input impedance	$\geq$ 10,000 Ohms
(e)	Connector	Type TNC
(f)	Number of connectors	1

3.7. Output to Command Logic. The equipment shall include suitable circuitry to provide the following outputs from the active register: ~~in response to the data transfer pulse.~~

(a)	Output format	12 most significant bits of binary data per channel
(b)	Impedance of command logic	$\geq$ 10,000 Ohms
(c)	Binary output voltages	"1" = 5.5 ± 0.5 v "0" ≤ 0.5 v
(d)	Connector	Bendix Pygmy
(e)	Number of connectors	1

3.8. Telemetry Ouput. A buffer storage register shall be provided which will accept data from the active register and hold it for sampling by the telemetry equipment. The buffer storage register shall have sufficient capacity to hold simultaneously data from all four channels. Previous entries shall be erased at such time as updating data is entered. The output from the buffer storage register shall be as follows:

(a)	Output format	A minimum of 23 bits and 1 reliability bit for each of four channels. More bits shall be used if necessary to meet specified resolution.
(b)	Binary output voltages	"1" = 5.5 ± 0.5 v "0" ≤ 0.5 v
(c)	Output impedance	600 ohms
(d)	Connector	Bendix Pygmy
(e)	Number of connectors	2

3.9. Telemetry Data Transfer Pulse Input. The equipment shall accept the following command pulse as a signal to transfer range data from the active register to the buffer storage register. Only one data transfer pulse input will be provided; distribution to each of the four channels shall be made within the Range Data Extraction equipment.

(a)	Amplitude	5.5 ± 0.5 v
(b)	Duration	5 microseconds
(c)	Time between pulses	0.25 seconds
(d)	Input impedance	$\gtrsim$ 10,000 ohms
(e)	Connector	Type TNC
(f)	Number of inputs	1

3.10. Monitoring Points. Monitoring points shall be connected and signals shall be provided as required by AROD-SPEC-5. Seventeen monitoring points shall be provided as follows:

(a) Range tone inputs--four on each of four channels
(b) 4.684 MHz input from frequency synthesizer

In addition, all input DC voltages shall be connected to the monitoring point connector; no signal processing is required on these voltages.

3.11. Test Points. Test points shall be provided and color coded as required by AROD-SPEC-5. Test points shall be provided for the following:

(a) Reference frequency input from frequency synthesizer
(b) Range tone inputs from receiver
(c) Range tone outputs
(d) Reference tones generated within the equipment
(e) Outputs of active register
(f) Necessary test points for troubleshooting

Additional test points shall be provided as deemed advisable for checking performance of the equipment.

APPENDIX II

SINGLE SIDEBAND MIXING PROCESS

SINGLE SIDEBAND MIXER PROCESS

The phase coherent reference frequencies mixed with the incoming range tones are developed in the phase reference generator by modulating the corresponding reference tones by 2.287 KH_z sine waves in single sideband mixers to obtain the lower sideband. The single sideband mixers give good rejection of the unwanted sideband without elaborate filtering. The single sideband mixers are composed of two balanced modulators with the outputs added together to give the required phase of the lower sideband. This function is represented by the trigonometric identity:

$$\cos (\omega_a - \omega_b) \quad t = \cos \omega_a t \ \cos \omega_b t + \sin \omega_a t \ \sin \omega_b t$$

To demonstrate that the phase data of the incoming range tones are conserved, consider the phase reference tone outputs from the phase reference generator to be sine waves with arbitrary phases:

$$\begin{aligned} 2.342\ MH_z &: \quad \sin \omega_1 t + \alpha \\ 73.187\ KH_z &: \quad \sin \omega_2 t + \beta \\ 2.287\ KH_z &: \quad \sin \omega_3 t + \gamma \\ 71.47\ H_z &: \quad \sin \omega_4 t + \delta \end{aligned}$$

The tones generated by the single sideband modulators are:

$$\begin{aligned} T_1 &= \cos \left\{(\omega_1 - \omega_3)\ t + \alpha - \gamma\right\} \\ T_2 &= \cos \left\{(\omega_2 - \omega_3)\ t + \alpha - \gamma\right\} \end{aligned}$$

The four reference tones are transmitted to a transponder and return with a relative time delay, τ, as:

$$\begin{aligned} &\sin\{\omega_1 \ (t - \tau) + \alpha\} \\ &\sin\{\omega_2 \ (t - \tau) + \beta\} \\ &\sin\{\omega_3 \ (t - \tau) + \gamma\} \\ &\sin\{\omega_4 \ (t - \tau) + \delta\} \end{aligned}$$

The two higher frequency range tones are mixed with the corresponding single sideband tones to give:

$$2 \sin\left\{\omega_1 (t-\tau) + \alpha\right\} \cos(\omega_1 - \omega_3)\ t + \alpha - \gamma =$$

$$\sin\left\{(2\omega_1 - \omega_3)\ t - \omega_1\tau + 2\alpha - \gamma\right\} + \sin\left\{\omega_3\ t - \omega_1\tau + \gamma\right\}$$

and likewise:

$$\sin\left\{(2\omega_2 - \omega_3)\ t - \omega_2\tau + 2\beta - \gamma\right\} + \sin\left\{\omega_3\ t - \omega_2\tau + \gamma\right\}$$

where only the difference components are sent to the phase trackers. The four tones seen by the phase tracking loops are, therefore:

$$\sin(\omega_3\ t - \omega_1\tau + \gamma)$$
$$\sin(\omega_3\ t - \omega_2\tau + \gamma)$$
$$\sin(\omega_3\ t - \omega_3\tau + \gamma)$$
$$\sin(\omega_4\ t - \omega_4\tau + \delta)$$

The phase trackers then add phase lags to corresponding reference tones until they equal these signals as follows:

$$\sin(\omega_3\ t - \theta_1 + \gamma) = \sin(\omega_3\ t - \omega_1\tau + \gamma)$$

$$\sin(\omega_3\ t - \theta_2 + \gamma) = \sin(\omega_3\ t - \omega_2\tau + \gamma)$$

$$\sin(\omega_3\ t - \theta_3 + \gamma) = \sin(\omega_3\ t - \omega_3\tau + \gamma)$$

$$\sin(\omega_4\ t - \theta_4 + \delta) = \sin(\omega_4\ t - \omega_4\tau + \delta)$$

APPENDIX III

ACCEPTANCE TEST PROCEDURE

TEST DATA SHEETS S/N 1 AND S/N 2

RYAN ELECTRONICS

REPORT NO. 53465-1

ACCEPTANCE TEST PROCEDURE

1.0 SCOPE

1.1 General - This document covers the Procedure for Testing the Range Data Extraction Equipment, Ryan Model 534, to demonstrate compliance with the requirements of Contract NAS8-5481.

2.0 REQUIREMENTS

2.1 Tests Required - The following tests shall be performed:

	Test	Paragraph
(1)	Min. Range	3.1
(2)	Range Rate	3.2
(3)	Inhibit Operation	3.3
(4)	Transfer Operation	3.4
(5)	Range Output to Telemetry	3.5
(6)	Range Output to Command Logic	3.6
(7)	Reference Tone Signals	3.7
(8)	Reliability Signal	3.8
(9)	Monitored Outputs	3.9

2.2 Standard Test Conditions - All laboratory tests shall be performed under the following standard test conditions unless otherwise specified.

(1)	Temperature	Room Ambient (20° to 30°C)
(2)	Humidity	Room Ambient to 80% relative
(3)	Pressure	Normal Ground
(4)	Vibration	Normal Bench
(5)	Warm-up	Three Minutes
(6)	Power	115 VAC

3.0 PERFORMANCE TESTS

3.1 Minimum Range - Measure the ability of the RDEE to provide digital range readouts as follows:

(1) Test Setup - The test setup shall be as shown in Figure 1. Check the phase and gain calibration of the reference signals.

(2) Measurement - With the reference signals connected as range tone inputs, observe the reading of the active register. When a reading of zero is obtained, the minimum range is measured. Note: Fluctuations of the high resolution counters is to be expected because of transient signals and noise.

3.2 Range Rate - Measure the ability of the RDEE to track rate changes up to 9000 meters/second.

Note: This test cannot be accomplished because a calibrated range - rate simulator is not available.

3.3 Inhibit Operation - Ascertain that the range data is inhibited from updating when the range data inhibit pulse is present.

(1) Test Setup - The test setup shall be as shown in Figure 1.

(2) Measurement - Apply the following signal to the range data inhibit pulse input line:

Amplitude	5.5 ± 0.5V
Duration	Approx. 5 microseconds
PRF	" 100 Hz.

Allow the phase of the range tones to vary while observing the output range data and the inhibit signal on the scope. Observe that the range data does not change when the inhibit signal is present. Record the observation on the data sheet.

3.4 Transfer Operation - Determine that the telemetry data transfer signal transfers range data from the active registers to the buffer storage registers.

(1) Test Setup - The test setup shall be as shown in Figure 1.

(2) Measurement - Apply the following signal to the telemetry data transfer pulse input line:

Amplitude	5.5 ± 0.5V
Duration	5 microseconds
Time between pulses	0.25 seconds min.

Observe range data transfer from the active register to the buffer storage register. Also note the active counters are inhibited during the transfer operation. Record the observation on the data sheet.

3.5 Range Output to Telemetry - Determine that the correct signals are available at the output of the buffer storage register.

(1) Test Setup - The test setup shall be as shown in Figure 1.

(2) Measurement - Using an oscilloscope, determine that a logical "1" from the 23 bits of each channel is 5.5 ± 0.5 volts and a logical "0" is ≤ 0.5 volts. Note any discrepancies on the data sheet.

3.6 Range Output to Command Logic - Determine that the correct signals are available at the output of the command logic buffers.

(1) Test Setup - The test setup shall be as shown in Figure 1.

(2) Measurement - Using an oscilloscope, determine that a logical "1" from the 12 bits of each channel is 5.5 ± 0.5 volts and a logical "0" is ≤ 0.5 volts. Note any discrepancies on the data sheet.

3.7 Reference Signals - Measure the output reference signals.

(1) Test Setup - The test setup shall be as shown in Figure 1.

(2) Measurement - Using a frequency counter and an oscilloscope, determine that the reference signals meet the following requirements:

Frequency:	2.342	MHz
	73.1875	KHz
	2.2871	KHz
	71.47	Hz
Amplitude:	2.0 volts	± 1db (sine wave)

Record results on the data sheet.

3.8 Reliability Signal - Measure the reliability signal output from the four channels.

(1) Test Setup - The test setup shall be as shown in Figure 1. Reliability signals are available at the following pins: CH.1, J2-p; CH.2, J2-PP; CH.3, J3-p; CH.4, J3-PP.

(2) Measurement - When the equipment is "locked-on", the reliability signal shall be ≤ 0.5 volts. Record measurements on data sheet.

3.9 Monitored Outputs - Determine that the signals required for external monitoring are available.

(1) Test Setup - The test setup shall be as shown in Figure 1.

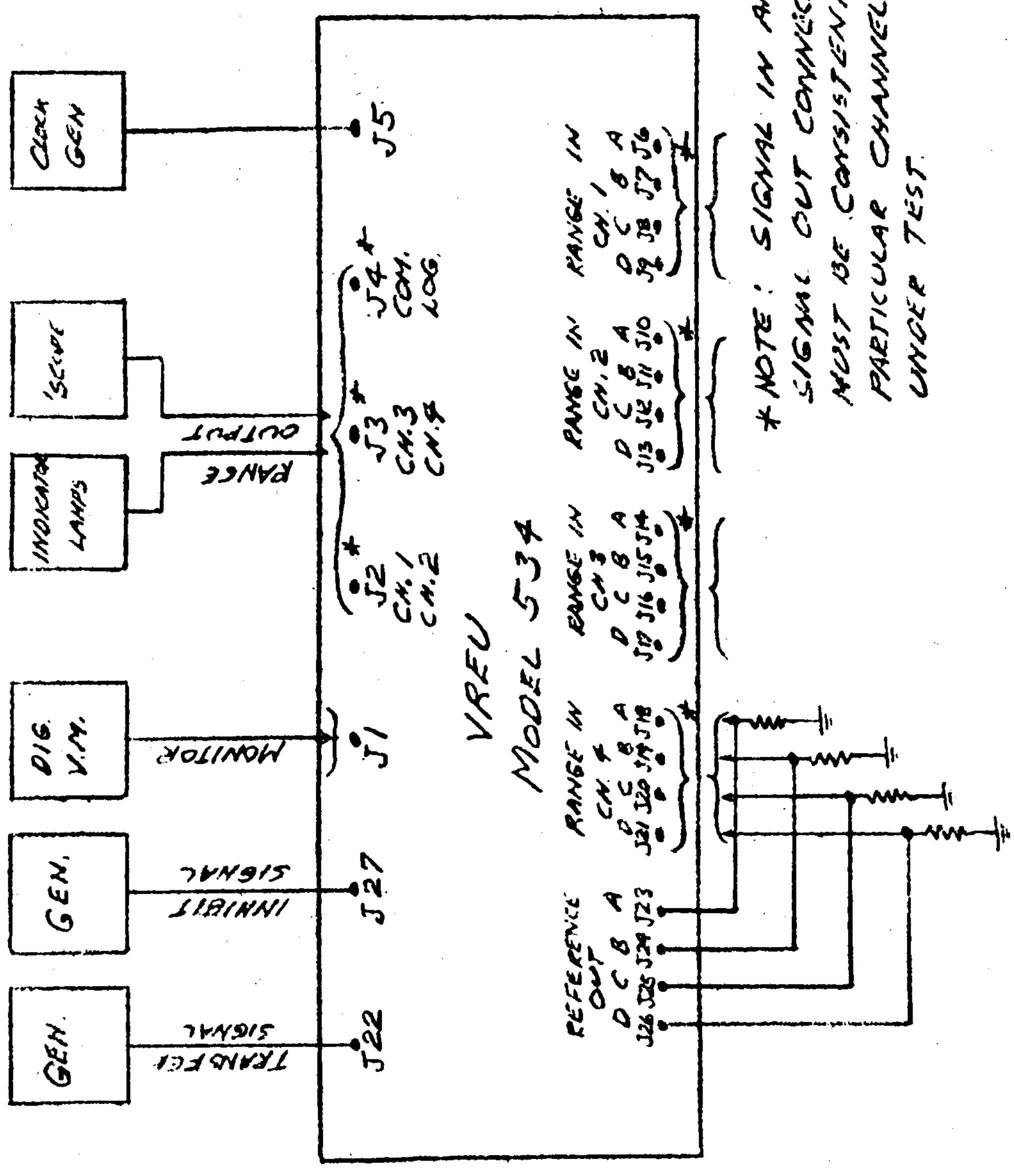
(2) Measurement - Measure the following output signals with the dc digital voltmeter. Record results on the data sheet.

(a) Range tone inputs (4 on each of 4 channels): Amplitude - 0 to 5 vdc depending on input signal amplitude.

(b) Reference signal input: 2 vdc

(c) DC power supply voltages:

+	7	vdc
+	12.0	vdc
-	6.0	vdc



*NOTE: SIGNAL IN AND SIGNAL OUT CONNECTIONS MUST BE CONSISTENT FOR PARTICULAR CHANNEL UNDER TEST

FIGURE 1

R-206-A

RYAN ELECTRONICS

REPORT NO. 53465-1

Test ACCEPTANCE — Date FEB 20, 1964

Eqpt. MODEL 534 — Test Engr. P.V. LATHROP

Serial No. 1 — Witness W.M. CURRY

Para.	Test	Reqmnt.	Measured
3.1	Min. Range	0	CH.1 0 CH.2 CH.3 0 CH.4
3.2	Range Rate	9000 meters/sec.	- - -
3.3	Inhibit	No updating	OK
3.4	Transfer	Transfers Signal	OK
3.5	Range Output	Logical "1"	+5.43 VDC
		Logical "0"	+0.01 VDC
3.6	Command Logic Output	Logical "1"	+5.5 VDC
		Logical "0"	0.0 VDC
3.7	Reference Signals	2.342 MHz	2342007.3 Hz
	INPUT REF = 4,684,014.6	2.0 volts ± 1db	2.0 V P-P
	+0	73.1875 KHz	73187.7 KHz
	−0.1 Hz	2.0 volts ± 1db	2.0 V P-P
	MEASURED ON HP 524D	2.2871 KHz	2287.1 Hz
		2.0 volts ± 1db	2.0 V P-P
		71.47 Hz	71.5 Hz
		2.0 volts ± 1db	2.0 V P-P
3.8	Reliability Signal	Locked on = 5.5±0.5 vdc	+5.46 VDC
	Channel 1	Search ≤ 0.5 vdc	0.0 VDC
	Channel 2	Locked on = 5.5±0.5 vdc	
		Search ≤ 0.5 vdc	
	Channel 3	Locked on = 5.5±0.5 vdc	+5.47 VDC
		Search ≤ 0.5 vdc	0.0 VDC
	Channel 4	Locked on = 5.5±0.5 vdc	—
		Search ≤ 0.5 vdc	—

Para.	Test	Reqmnt.	Measured
3.9	Monitored Signals		
	Range Tone Inputs	0-5 vdc	
	Channel 1A	"	3.28 VDC
	1B	"	3.10 VDC
	1C		2.60 VDC
	1D	"	2.70 VDC
	2A	"	
	2B	"	
	2C	"	
	2D	"	
	3A	"	3.35 VDC
	3B	"	2.83 VDC
	3C	"	2.32 VDC
	3D	"	2.30 VDC
	4A	"	
	4B	"	
	4C	"	
	4D	"	
	Reference Signal Input	2 vdc	2.8 VDC
	+ 7.0 vdc		+7.0 VDC
	+ 12.0 vdc		+12.0 VDC
	- 6.0 vdc		-5.9 VDC

S/N 1 COMPRISES:
CLOCK BOARD #534C0053-G1 S/N 1
CHANNEL 1:
534C0036-G1 S/N 2
534C0036-G2 S/N 2
534C0061-G1 S/N 3
CHANNEL 3:
534C0036-G1 S/N 1
534C0036-G2 S/N 3
534C0061-G1 S/N 1

RYAN ELECTRONICS

REPORT NO. 53465-1

Test ACCEPTANCE   Date FEB. 28, 1964
Eqpt. MODEL 534   Test Engr. P.V. LATHROP
Serial No. 2   Witness W.M. CURRY

Para.	Test	Reqmnt.	Measured
3.1	Min. Range	0	CH.1 — CH.2 0 CH.3 - CH.4 0
3.2	Range Rate	9000 meters/sec.	— — —
3.3	Inhibit	No updating	OK
3.4	Transfer	Transfers Signal	OK
3.5	Range Output	Logical "1"	+ 5.35 VDC
		Logical "0"	+ 0.018 VDC
3.6	Command Logic Output	Logical "1"	+ 5.35 ± .02 VDC
		Logical "0"	+ 0.018 VDC
3.7	Reference Signals	2.342 MHz	2342008 Hz
		2.0 volts ± 1db	2.12 V P-P
		73.1875 KHz	73187.5 Hz
		2.0 volts ± 1db	2.0 V P-P
		2.2871 KHz	2.287 KHz
		2.0 volts ± 1db	2.0 V P-P
		71.47 Hz	71.5 Hz
		2.0 volts ± 1db	2.0 V P-P
3.8	Reliability Signal Channel 1	Locked on = 5.5±0.5 vdc	—
		Search $\leq$ 0.5 vdc	—
	Channel 2	Locked on = 5.5±0.5 vdc	+5.341 VDC
		Search $\leq$ 0.5 vdc	+ 0.056 VDC
	Channel 3	Locked on = 5.5±0.5 vdc	—
		Search $\leq$ 0.5 vdc	—
	Channel 4	Locked on = 5.5±0.5 vdc	+5.349 VDC
		Search $\leq$ 0.5 vdc	+0.007 VDC

Data Sheet

Para.	Test	Reqmnt.	Measured
3.9	Monitored Signals		
	Range Tone Inputs	0-5 vdc	
	Channel 1A	"	______
	1B	"	______
	1C		
	1D	"	______
	2A	"	+3.22 VDC
	2B	"	+2.64 VDC
	2C	"	+2.33 VDC
	2D	"	+2.898 VDC
	3A	"	______
	3B	"	______
	3C	"	______
	3D	"	______
	4A	"	+3.226 VDC
	4B	"	+3.065 VDC
	4C	"	+2.628 VDC
	4D	"	+2.695 VDC
	Reference Signal Input	2 vdc	+2.8 V
	+ 7.0 vdc		+6.999 VDC
	+ 12.0 vdc		+12.00 VDC
	- 6.0 vdc		-6.00 VDC

S/N 2 COMPRISES:
CLOCK BOARD # 534C0053-G1 S/N 2
CHANNEL 2:
534C0036-G1 S/N 3
534C0036-G2 S/N 1
534C0061-G1 S/N 2
CHANNEL 4:
534C0036-G1 S/N 4
534C0036-G2 S/N 4
534C0061-G1 S/N 4

Data Sheet